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Pre- and post harvest factors affecting sorghum production (*Sorghum bicolor* L. Moench) among smallholder farming communities

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Abstract

A farm survey was conducted on Sorghum (*Sorghum bicolor* L. Moench) as a staple cereal crop adapted in arid and semi – arid lands. The objective was to determine pre - and post - harvest factors affecting sorghum production. Ninety five farmers were sampled using snowballing sampling method in six sorghum growing sub – counties (Siaya, Bondo, Njoro, Rongai, Kibwezi and Kathonzweni) to gather information on pre - and post – harvest. Data collected on source of sorghum seeds, varieties storage form and were analyzed using descriptive statistic cross tabulation SPSS version 20 software. Sources of sorghum seed were farmers own seed (33.7%), from neighbour or market (24.2%) and farm input distributors (42.1%). The results showed that 44.2% and 55.8% of the farmers preferred local and improved sorghum varieties respectively. Sorghum grains were either stored in shelled form (88.4%) or on panicles (11.6%). This study further established that farmers maintain a diversity of sorghum landraces unique in their adaptation, food quality, grain yield and quality of harvested products resistance. The results of this study can be used to explain the perennial food insecurity in these regions known to have huge potential for sorghum production.

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Introduction

Sorghum (*Sorghum bicolor* L. Moench) is a cereal crop utilized as human food with a potential of providing food security in arid and semi-arid lands where many cereal crops produce little yield (Mamoudou, 2006). It is characterized by extensive root system and waxy bloom on leaves that reduces water loss (Paterson, 2008). Sorghum grows in areas of altitude 500 metres - 1700 metres above sea level (m a.s.l.), with an annual rainfall of 300mm. Among other areas, sorghum is produced in Makueni (1385m a.s.l), Siaya (1190m a.s.l) and (1967m a.s.l) Nakuru County. The production areas are characterized as semi-arid low lands, moist humid and cold highlands. Sorghum can replace maize (*Zea mays* L.) as staple food in case of crop failure as it is closely related to maize in utilization hence an alternative crop in marginal areas (Swigonova *et al.,* 2004). Sorghum is used as human food as well as animal feed and industrial raw material (Mamoudou *et al,* 2006). As food, the grain is used in making porridge and thick porridge. It has got a large germplasm collection that provides great opportunities for a sustainable crop production (Huang, 2004).

Sorghum production is mainly by small scale farmers. Production constraints are lack inputs and plant poor quality seeds as own saved seeds, obtained from neighbours or market, diseases and pests, these results in low yields (Muliokela *et al.*, 2011). The demand for sorghum grains by the brewing industry is high yet the amount produced by farmers is low as it averages at 0.85 t ha^{-1} (Gerda and Christopher, 2007). Low production is also attributed to infestation by the birds like sudan dioch (*Quelea quelea*), pests, poor drying of harvested grains and storage practices (Bannett and Hunter, 2003). Seed quality is important for a good seedling establishment and crop development, yield and quality grains (Muasya *et al.*, 2008).

The majority of farmers thresh their seed from panicles by beating with sticks or rubbing the panicle on a hard surface like a rough stone or storing it on panicles. This contributed to high mechanical damage due to the breaking of seeds into small pieces hence reducing the seed quality (Songa *et al.*, 1995). When seeds within a seed lot are broken into pieces, the embryos are damaged hence reducing the germination capacity of the seeds. The practice of drying sorghum panicles in direct sunlight by farmers in the sub – counties of study might have led to reduced seed quality. When seeds are dried at high temperatures, they lose vigour and viability (Harrison and Perry, 1976). Loss in quality and quantity in cereal grains during storage is caused by fungi. The ecosystem within stored grain structures is limited in microbial species because of human efforts to maintain grain quality (Wicklow, 1995). Temperature and air movement continually change within the grain mass. This causes moisture to migrate, resulting in areas with moisture conditions that allow storage fungi to grow and slowly impact grain quality (Sinha, 1992). The amount of water available in an environment is measured in moisture content fluctuates in dry environment in equilibrium with the relative humidity of the air surrounding this matrix (grain mass) (Yanagita, 1990). This study aimed at determining pre - and post - harvest factors affecting sorghum production. Area of study was Siaya and Bondo sub - counties in Siaya county, Rongai and Njoro sub - counties in Nakuru county, Kathonzweni and Kibwezi sub - counties in Makueni County.

Materials and methods

Sampling procedure

A snowball sampling method was used in the six sub – counties of Siaya, Bondo Njoro, Rongai, Kibwezi and Kathonzweni between10th August - 15th September 2013. Kibwezi is classified as Lower Midland (LM5, LM6) with some regions in transitional zone towards Upper Midland (UM). Kathonzweni is LM3, LM4 and LM5 (Jaetzold *al.*, 2006). Rongai has three agro-ecological zones, Lower Highland 3 (LH3), Upper Midland 2 (UM2) and Upper Midland 3 (UM3). Njoro is UH1, UH2 and LH, Bondo and Siaya (LM2 LM3) (Jaetzold *et al.*, 2006). Each study district was considered a homogeneous sampling area. Administrative divisions, location, sub-location and villages within each sub - county

were appropriately represented during sampling. A total of 95 farmers were randomly selected and interviewed using a structured questionnaire. Additional post- harvest observations were made on handling of the harvested sorghum grains.

Land holding and farmers traits of preference in growing sorghum

The information on farmer's residential address (village, sub-location, location and division) within a district, age, land acreage, source of sorghum seed, type of sorghum, traits of preference, factors influencing harvesting, type and duration of storage. These variables were considered to have influence on pre- and post- harvest handling of sorghum.

Traits of preference in sorghum grown and handling after harvesting

The information on farmer preference on the sorghum varieties they grow, source of seed, factors influencing harvesting of sorghum and handling after harvesting, storage facilities used by the respondents and storage duration of sorghum in months.

Statistical analysis

Data collected on farmers' traits, land holding in acreage, age, gender, source of sorghum seed, type of sorghum, traits preference, factors influencing harvesting, type and duration of storage of sorghum grains were subjected to descriptive statistics using SPSS computer package version 20 software.

Results

Land size of sorghum among respondent farmers

The majority (85-100%) of the respondents in the sub – counties of study, except in Kibwezi sub – county had a land holding of more than two hactares of land, in Bondo and Kibwezi sub - counties(1.1- 6.7%) had land holding of 1.1-2.0ha, in Kibwezi and Siaya sub - counties(3 – 6%) had 0.0-1.0ha of land(Fig.1).

Table 1. Farmers' source of sorghum seed.

	Percent of respondent farmers in the six sub - counties study						
Source (s) of seed	Bondo	Siaya	Kibwezi	Kathonzeni	Rongai	Njoro	Means
Own seed	66.7	56.2	18.5	30.0	21.4	9.1	33.6
Neighbour/Market	13.3	0.0	29.6	30.0	42.9	27.3	23.8
Input Distributor	20.0	43.8	51.9	40.0	35.7	63.6	42.5
Total (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 2. Farmers' preference in different sorghum varieties in the sub - counties of study.

	Percent preference of sorghum varieties in the sub - counties of study						
Reasons to grow sorghum	Bondo	Siaya	Kibwezi	Kathonzweni	Rongai	Njoro	Means
HY	6.7	0.0	3.7	10.0	100.0	9.1	21.6
SI	80.0	68.8	6.3	40.0	0.0	90.9	41.2
GS	0.0	6.2	3.7	10.0	0.0	0.0	3.9
HY+FS+SI	6.7	6.2	3.7	0.0	0.0	0.0	2.8
HY+FS+SI+EM+GS	0.0	0.0	22.2	40.0	0.0	0.0	12.4
FS+EM	0.0	0.0	3.7	0.0	0.0	0.0	0.7
HY+FS+EM	0.0	6.2	0.0	0.0	0.0	0.0	1.2
Total (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Where: HY- High yielding, SI- Source of income, GS- Good storability, FS- Food security
EM- Early maturity

Sorghum varieties, source of sorghum seeds grown

Sorghum varieties grown by the famers interviewed in the six sub - counties varied as majority (50 - 72%) of the respondents planted improved sorghum varieties except in Rongai and Njoro. The local sorghum varieties were popular (50 - 93%) in Siaya, Kathonzweni, Rongai and Njoro sub - counties. The respondent farmers who were growing the improved

sorghum varieties were highest (78%) in Kibwezi sub - county (Fig. 2). Many (56.2 - 66.7%) of the respondent used their own saved seed to establish sorghum crop for the next season. The respondents who sourced sorghum seeds from either their neighbour/ market were in Kathonzweni and Rongai sub - counties (30 – 42.9%). The respondent farmers also sourced seeds from inputs distributors in Kibwezi and Njoro sub - counties (51.9 – 63.6%) (Table 1).

Table 3. Handling of harvested sorghum grains.

	Percent handling of harvested sorghum grains in six sub - counties of study						
Handling(s)	Bondo	Siaya	Kibwezi	Kathonzweni	Rongai	Njoro	Mean
SDBG	13.4	18.8	41.7	30.0	0.0	0.0	17.31
SDPE	80.0	81.2	55.6	70.0	100.0	100.0	81.13
SDARH	0.0	0.0	3.7	0.0	0.0	0.0	0.62
SDBG+SDPE	6.7	0.0	0.0	0.0	0.0	0.0	1.12
Total (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Where: SDBG- sun drying on bare ground, SDPE- sun drying on polyethene , SDARH- sun drying atop roof house.

Table 4. Storage form of sorghum grains.

	Percent of storage form of sorghum grains in the six sub - counties study						
Storage form	Bondo	Siaya	Kibwezi	Kathonzweni	Rongai	Njoro	Mean
Shelled	86.7	100.0	96.3	100.0	64.3	81.8	88.18
Panicle	13.3	0.0	3.7	0.0	35.7	18.2	11.82
Total (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Traits Preferred, factors influencing sorghum harvesting in the six districts of study

Traits preferred by the farmers in the landraces grown were high yields, good storability, early maturing, and resistance to birds. Percentage of farmers preferring high yields in sorghum planted was reported in Rongai with 100%, good storability (3.72 - 10%) in Kibwezi, Siaya and Kathonzweni. High yielding, food security, source of income, early maturity and good storability only in Kibwezi and Kathonzweni (22.2 - 40%) (Table 2).

Table 5. Storage structure used for sorghum grains.

	Percent storage structures in the six sub - counties of study						
Storage structure	Bondo	Siaya	Kibwezi	Kathonzweni	Rongai	Njoro	Mean
Traditional granary	20.0	6.2	22.2	10.0	14.3	0.0	12.12
Improved granary	0.0	0.0	48.1	60.0	71.4	63.6	40.52
Living room/house	80.0	93.8	29.6	30.0	14.3	36.4	47.35
Total (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 6. Storage container used for sorghum grains.

	Percent storage container/bag in the six sub - counties of study						
Storage container/bag	Bondo	Siaya	Kibwezi	Kathonzweni	Rongai	Njoro	Mean
Sisal bag	26.7	6.6	18.5	30.0	0.0	0.0	27.20
Gunny (manila) bag	66.7	93.8	77.8	70.0	100.0	81.8	68.05
Plastic container	0.0	0.0	3.7	0.0	0.0	18.2	17.28
Reed basket	6.7	0.0	0.0	0.0	0.0	0.0	0.00
Total (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.00

Handling of sorghum grains after harvesting

The respondents' farmers in the surveyed sub - counties dried their sorghum grains on bare ground (30 - 41.7%) in Kathonzweni and Kibwezi sub – counties. Sorghum drying on the sun on polyethene sheet was a common practice in sub – counties of study (55.6 - 100%). Sorghum drying on top of roof houses was only present among respondents in Kibwezi sub - county. Drying on bare ground and on polyethene sheet was only in Bondo sub - county (Table 3). Dried sorghum grains were either stored on panicle (3.7 - 35.7%) in only Kibwezi, Bondo and Rongai or in shelled form (64.3-100%) in the sub - counties of study (Table 4). Sorghum grains were stored in different storage structures; traditional granary was used by (20 - 22.2%) of the respondents and it was lacking among respondents in Njoro sub - county in improved granary (49.1-71.4%) in sub - counties of study except in Bondo and Siaya sub - counties and in living room/house was used to store sorghum grains in the six study sub - counties (14.3 – 93.8%) (Table 5). The storage container /bag of sorghum grains were sisal bags was common in the six sub - counties (6.6-30%) except in Rongai and Njoro sub – counties. Gunny bags were used (66.7-100%) in the sub – counties of study. Plastic container (3.7-18.2%) was only used in Kibwezi and Njoro sub - counties. Reed basket was only used in Bondo sub – county (6.7%) (Table 6). Duration of the stored grains among the respondents also varied as, 1 - 3months (18.8 - 40%) in all districts except in Njoro and Rongai (0.0%) storage duration. In the six districts 4 - 6months (14.3 - 56.2%), 7 - 9 months (6.2 - 54.4%) and 10 - 12months (9.1 - 30%) was common storage duration with exception of 22 - 24 months (3.7%) in Kibwezi sub – counties (Table 7).

Table 7. Storage duration (months) of sorghum grains.

	Percent storage duration in months in districts of study						
Storage (months)	Bondo	Siaya	Kibwezi	Kathonzweni	Rongai	Njoro	Mean
1-3	40.0	18.8	22.2	30.0	0.0	0.0	18.5
4 - 6	33.3	56.2	40.7	20.0	14.3	36.4	33.5
7 - 9	6.7	6.2	22.2	20.0	14.3	54.5	20.7
10 - 12	20	18.8	11.1	30.0	71.4	9.1	26.7
22 - 24	0.0	0.0	3.7	0.0	0.0	0.0	0.6
Total (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Discussion

The land size in acres cultivated for sorghum production in the sub - counties of study was relatively small. This might have led to low production in a unit area. The production in Kenya which averages at 0.85 t ha^{-1} is low with a high demand for sorghum in brewing industry (Gerda and Christopher, 2007). Production constraints are rainfall variability, lack of certified seeds, socio-economic, pests like birds sudan dioch (*Quelea quelea*), diseases and post harvest losses (Gerda and Christopher, 2007).

The type of sorghum planted by the farmers in the sub - counties of study preferred local varieties (53.7%) compared to improved varieties (46.3%). The local sorghum varieties are grown by farmers based on preference selection ensuring the crop diversity is maintained for decades. The landraces are unique in their adaptation, food quality, grain yield, quality of harvested products, biotic stress resistance and post - harvest processing. Most small scale farmers who plant landraces crop varieties in sub - Saharan Africa use on-farm produced and saved seed whose quality is usually poor (Muliokela, 1999). Sorghum has diverse morph-types in many of the sorghum growing regions of Africa, often as in distinct races of *Sorghum bicolor* that form a crop–wild–weed complex (Ejeta and Grinier, 2005). Majority of the farmers in these regions grow sorghum landraces due to the variable traits preferred by farmers except for those who grow hybrids (Muui *et al*., 2013). In India, sorghum varieties were planted by many farmers that were high yielding, good in quality for both grain and fodder and resistance to biotic and a biotic stresses. Many of the farmers in Mali considered varieties

adaptation to different agro ecological conditions, yield and resistance to different biotic stresses (Sthapit *et al.*, 1999). The germplasm of sorghum collected from the sub – counties of study provides greater genetic variability and can furnish useful traits to broaden the genetic base of the under-utilized crop species. The need to conserve indigenous species of different crop as most of the indigenous food crops are threatened by rapid adoption of highly improved crop varieties many of which are introduced and poorly adapted. Together with genetic resources, indigenous knowledge associated with the cultivation, utilisation and conservation of indigenous crops is also endangered. Unless something is done to conserve and re-popularise their use, this natural resource may be lost forever (FAO, 1996). Sorghum crop has a large germplasm collection that provides great opportunities for sustainable crop production (Huang, 2004).

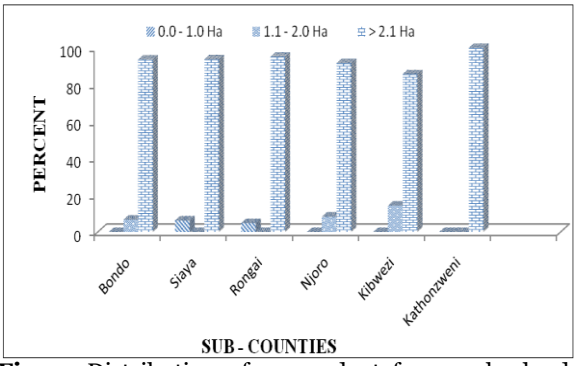

Fig. 1. Distribution of respondent farmers by land size in six sub – counties.

Results of this study show that own saved seed contributes the largest proportion of the informal seed sector. This is in agreement with the report that approximated that 80% of the farmers save their own seeds for planting the next season (Muliokela, 2011). Sources of seed for planting most indigenous crops include farm saved, local markets, borrowed from neighbours and relatives (Maundu *et al.*, 1999). The informal seed system includes methods such as retaining seed on-farm from previous harvests to plant the following season and farmer-to-farmer seed exchange net works, buying from the neighbour/market (Cormwell *et al.*, 1992). A study in Ethiopia indicated that, most seed transactions take place between neighbours and relatives because farmers prefer to see the crop stand in a neighbour's farm before deciding on obtaining the variety (Singh, 1990). The role of neighbours and relatives in traditional seed systems is not new and involves farmer-to-farmer seed exchange, seed donations and other transfer methods to meet social obligations (Maundu *et al.*, 1999). In an earlier study conducted in Mbeere sub – county in Kenya showed that, only 10% of farmers use certified seed for other crops while 90% relied on locally selected seeds (KFSSG, 2008). Maintaining sorghum crop production yield and produce quality which give the farmer maximum return requires good seed which carries the genetic, physiological and physical quality aspects (Muasya, 2008). Majority of farmers use farm saved seeds to plant the following season while those who cannot save enough seed borrow from neighbours, relatives or buy from the market. The role of neighbours and relatives in traditional seed systems is not new and involves farmer-to-farmer seed exchange, seed donations and other transfer methods to meet social obligations (Cormwell *et al.,* 1992). Many of the farmers' in Malawi obtains bean seed from neighbours, relatives and other local sources (Cromwell, 1993). Ethiopia many seed transactions take place between neighbours and relatives because farmers prefer to see the crop stand in a neighbours' farm before deciding on obtaining the variety (Singh, 1990).

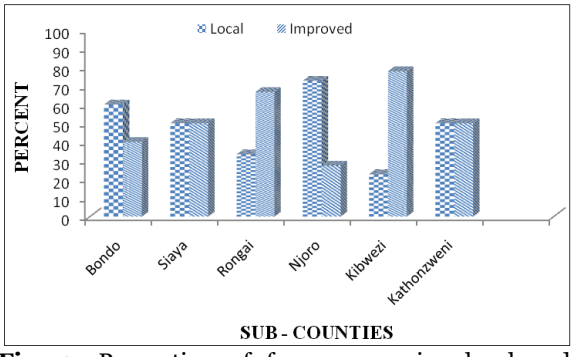

Fig. 2. Proportion of farmers growing local and improved sorghum varieties.

Sorghum variety, its quality to be used as food largely it will determine acceptability by the farmers and the adaptation to biotic stresses determines the survival in the field and in storage (Sthapit *et al.*, 1999). The ecosystem within stored grain structures is limited in

microbial species because of human efforts to maintain grain quality (Wicklow, 1995). The type of grain and storage structures, moisture, and temperature will influences the storage duration and quality of the stored grains. (Wicklow, 1995). In practice, temperature and air movement continually change within the grain mass, this causes moisture to migrate and resulting in areas with moisture conditions determines the grain quality (Sinha, 1992). The amount of water available in an environment is often measured in values of water activity (aw). The water activity in the dry environment fluctuates in equilibrium with the relative humidity of the air surrounding this matrix (grain mass) (Yanagita, 1990). The losses of grain quality and quantity are both physical, it leads to failure in marketing grain in high market value (World Bank, 2011).

Conclusion

The respondent farmers in the sub – counties maintained a diversity of sorghum landraces by cultural preferences and traditional practices like own seed, seed exchange from neighbour or buying from market with reference to uniqueness in adaptation, grain yield and good storage. The sub – counties have a high agricultural potential that would enhance food security by improve use of locally available germplasm and hybrid adapted to the environments. The survey established source of seed used by farmers, handling of sorghum after harvest. This could help promote sorghum as an industrial and food crop and also improve quality of seeds used by farmers.

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